

CLAIMS

What is claimed is:

- 1 1. A system to log a wellbore, comprising:
2 a logging tool adapted to be deployed in a wellbore and including at least one fiber optic
3 sensor;
4 a fiber optic line in optical communication with the fiber optic sensor; and
5 the fiber optic sensor adapted to transmit data on a real time basis through the fiber optic
6 line.
- 1 2. The system of claim 1, wherein the data comprises at least one measurement of the wellbore
2 environment.
- 1 3. The system of claim 1, wherein the data comprises status data from the logging tool.
- 1 4. The system of claim 1, wherein the fiber optic line is incorporated into a slickline.
- 1 5. The system of claim 4, wherein the logging tool is attached to the slickline.
- 1 6. The system of claim 1, wherein the fiber optic line is incorporated into a braided cable.
- 1 7. The system of claim 6, wherein the braided cable also includes at least one electrical
2 conductor.
- 1 8. The system of claim 6, wherein the logging tool is attached to the braided cable.
- 1 9. The system of claim 1, wherein the fiber optic line is deployed within a conduit.
- 1 10. The system of claim 9, wherein an actuation signal is sent through the conduit to actuate at
2 least one device located downhole.

- 1 11. The system of claim 10, wherein the actuation signal comprises a hydraulic signal.
- 1 12. The system of claim 11, wherein the at least one device comprises one of a packer, a shaped
2 charge, a flow control valve, a sleeve valve, a ball valve, a sampler, a sensor, a pump, or a tractor.
- 1 13. The system of claim 9, wherein the conduit is a tube.
- 1 14. The system of claim 9, wherein the conduit is a coiled tubing.
- 1 15. The system of claim 9, wherein the conduit is deployed within a coiled tubing.
- 1 16. The system of claim 9, wherein the logging tool is attached to the conduit.
- 1 17. The system of claim 1, wherein the fiber optic line is deployed through a stuffing box
2 installed on a wellhead.
- 1 18. The system of claim 17, wherein the stuffing box forms a seal with the fiber optic line.
- 1 19. The system of claim 1, wherein the fiber optic line is deployed from a reel located at a
2 surface of the wellbore.
- 1 20. The system of claim 19, wherein the reel is located on a vehicle.
- 1 21. The system of claim 19, wherein the logging tool is deployed and retrieved multiple times in
2 the same wellbore.
- 1 22. The system of claim 20, wherein the logging tool is deployed and retrieved from multiple
2 wellbores.

- 1 23. The system of claim 19, further comprising:
2 an optical slip ring functionally associated with the reel and the fiber optic line;
3 an acquisition unit attached to the fiber optic line at the surface;
4 the optical slip ring adapted to allow the transmission of optic data to the static acquisition unit
5 while the conduit and fiber optic line therein move on the reel in and out of the wellbore.
- 1 24. The system of claim 1, wherein the fiber optic line is optically connected to an acquisition
2 unit adapted to receive the data.
- 1 25. The system of claim 24, wherein the acquisition unit processes the data.
- 1 26. The system of claim 9, wherein:
2 a transmitter is located at a surface of the wellbore;
3 a modulator is located downhole;
4 the transmitter transmits an optical signal to the modulator; and
5 the modulator modulates the optical signal so that the return optical signal is encoded with the data.
- 1 27. The system of claim 1, wherein:
2 a transmitter is located at a surface of the wellbore;
3 a modulator is located downhole;
4 the transmitter transmits an optical signal to the modulator; and
5 the modulator modulates the optical signal so that the return optical signal is encoded with the data.
- 1 28. The system of claim 1, wherein:
2 a transmitter is located downhole; and
3 the transmitter sending optical signals through the fiber optic line based on the readings of the at
4 least one fiber optic sensor.
- 1 29. The system of claim 1, wherein the fiber optic sensor reflects a return optical signal back to
2 an acquisition unit with the relevant measurement encoded therein.

1 30. The system of claim 1, wherein the fiber optic sensor comprises at least one of a temperature
2 sensor, a pressure sensor, an acoustic sensor, a casing collar locator, a flow sensor, a chemical
3 property sensor, a gamma ray tool, an optical fluid analyzer, a gyro tool, a water detection sensor, a
4 gas detection sensor, an oil detection sensor, a differential pressure sensor, a spectrometer, an
5 inclinometer, a relative bearing sensor, a distributed temperature sensor, a distributed strain sensor, a
6 hydrophone, an accelerometer, a sonic tool, a resistivity sensor, or an induction sensor.

1 31. The system of claim 1, wherein the fiber optic line acts as a distributed temperature sensor.

1 32. The system of claim 1, wherein the fiber optic line acts as a distributed strain sensor.

1 33. The system of claim 1, wherein the fiber optic line acts as an acoustic array.

1 34. The system of claim 1, wherein a plurality of fiber optic lines are in optical communication
2 with the logging tool.

1 35. The system of claim 1, wherein optical signals sent through the fiber optic line actuate at
2 least one device located downhole.

1 36. The system of claim 35, wherein a photovoltaic converter receives the optical signal and
2 enables the actuation of the at least one device.

1 37. The system of claim 35, wherein the at least one device comprises one of a packer, a shaped
2 charge, a flow control valve, a sleeve valve, a ball valve, a sampler, a sensor, a pump, or a tractor.

1 38. The system of claim 1, wherein the fiber optic sensor comprises a piezoelectric material to
2 apply strain on a portion of the fiber optic line.

1 39. The system of claim 38, wherein the fiber optic sensor comprises a fiber Bragg grating
2 provided on the portion of the fiber optic line.

1 40. The system of claim 1, wherein the fiber optic sensor comprises a magneto-strictive coating
2 on at least a portion of the fiber optic line.

1 41. The system of claim 40, wherein the fiber optic sensor comprises a magnet to generate a
2 magnetic field to cause the magneto-strictive coating to apply strain on the at least a portion of the
3 fiber optic line.

1 42. The system of claim 1, wherein the fiber optic sensor comprises a spinner rotatable in
2 response to a well characteristic.

1 43. The system of claim 42, wherein the fiber optic sensor further comprises a magnet attached
2 to rotate with the spinner, the magnet to induce electrical energy in a coil.

1 44. The system of claim 43, wherein the fiber optic sensor further comprises a piezoelectric
2 material responsive to electrical energy from the coil to apply strain on a portion of the fiber optic
3 line.

1 45. The system of claim 42, further comprising a mirror, wherein the spinner comprises an
2 element having at least one opening, wherein rotation of the spinner causes the mirror to be
3 intermittently exposed to light in the fiber optic line through the opening.

1 46. The system of claim 1, wherein the fiber optic sensor comprises one of a spectrometer and a
2 refraction measurement device.

1 47. The system of claim 1, wherein the fiber optic sensor comprises one of a channel and
2 chamber containing a fluid, light transmitted through the fiber optic line to pass through the one of
3 the channel and chamber.

1 48. The system of claim 47, wherein the fiber optical sensor further comprises a first optical
2 fiber segment on one side of the channel or chamber, an a second optical fiber segment on another
3 side of the channel or chamber.

- 1 49. The system of claim 47, wherein the fiber optic sensor further comprises a reflector
2 proximate the channel or chamber
- 1 50. The system of claim 1, wherein the fiber optic sensor comprises an inclinometer having a
2 mass supported by plural optical fiber segments.
- 1 51. The system of claim 1, wherein the fiber optic sensor comprises a compass.
- 1 52. The system of claim 1, wherein the fiber optic sensor comprises a gamma ray detector.
- 1 53. The system of claim 52, wherein the gamma ray detector comprises a scintillating crystal
2 and an element to convert light photons generated by the scintillating crystal to one of an optical
3 signal and an electrical signal.
- 1 54. The system of claim 1, wherein the fiber optic sensor comprises resistivity electrodes.
- 1 55. The system of claim 54, wherein the fiber optic sensor comprises a piezoelectric element
2 responsive to at least one of the resistivity electrodes to apply strain on a portion of the fiber optic
3 line.
- 1 56. The system of claim 1, wherein the fiber optic sensor comprises an induction coil and a
2 piezoelectric element responsive to electric voltage of the induction coil to apply strain on a portion
3 of the fiber optic line.
- 1 57. The system of claim 1, further comprising:
2 a second fiber optic sensor coupled to the fiber optic line; and
3 wavelength division multiplexing elements to enable the fiber optic sensor to be responsive
4 to optical signals of different wavelengths.
- 1 58. The system of claim 1, further comprising:
2 a second fiber optic sensor coupled at the fiber optic line; and

3 time division multiplexing elements to enable communication with the fiber optic sensors at
4 different times.

1 59. The system of claim 1, further comprising:
2 a downhole modulator to modulate an optical signal in the fiber optic line.

1 60. The system of claim 59, wherein the modulator is an optical interferometer.

1 61. The system of claim 1, wherein the fiber optic line includes an end cut at a slanted angle.

1 62. The system of claim 59, wherein the modulator moves in relation to the fiber optic line to
2 cause the modulation of the optical signal.

1 63. The system of claim 59, wherein the modulator comprises a piezoelectric element to apply
2 strain on a portion of the fiber optic line.

1 64. A fiber optic flow sensor adapted to be disposed in a wellbore, comprising:
2 a fiber optic line carrying an optical signal;
3 a spinner adapted to spin when in contact with fluids flowing through the wellbore; and
4 a modulator functionally connected to the spinner, the modulator modulating the optical
5 signal depending on the spinning of the spinner.

1 65. The sensor of claim 64, wherein the modulator is located on the spinner and the spinner and
2 modulator are constructed so that the modulator becomes aligned with the fiber optic line at least
3 once every revolution of the spinner.

1 66. The sensor of claim 65, wherein:
2 a pulse is reflected through the fiber optic line each time the modulator becomes aligned
3 with the fiber optic line; and

4 an acquisition unit receives the reflected pulse and determines the velocity of the wellbore fluids
5 based on the frequency of reception of the reflected pulses.

1 67. The sensor of claim 65, wherein the spinner includes a blade coupled to a disc.

1 68. The sensor of claim 67, wherein the blade is located external to the housing and the disc is
2 located internal to the housing.

1 69. The sensor of claim 67, wherein the housing is sealed.

1 70. The sensor of claim 69, wherein the blade and the disc are magnetically coupled across the
2 housing.

1 71. The sensor of claim 67, wherein the modulator is located on the disc.

1 72. The sensor of claim 71, wherein the modulator is located at a side of the disc.

1 73. The sensor of claim 64, wherein the optical signal is modulated by imparting a strain on the
2 fiber optic line.

1 74. The sensor of claim 73, wherein the modulator comprises a fiber bragg grating incorporated
2 on the fiber optic line.

1 75. The sensor of claim 73, further comprising:
2 a permanent magnet coupled to the spinner;
3 a coil attached to a housing; and
4 wherein the permanent magnet and the coil become magnetically connected as the spinner
5 revolves.

1 76. The sensor of claim 75, wherein the magnetic connection generates a voltage that causes a
2 piezoelectric material mechanically coupled to the fiber optic line to constrict and strain the fiber
3 optic line.

1 77. A casing collar locator adapted to detect casing collars disposed in a wellbore, comprising:
2 a fiber optic line carrying an optical signal;
3 a magnetic device adapted to become magnetically connected to a casing collar as the
4 magnetic device passes the casing collar;
5 a modulator that is functionally connected to the magnetic device;
6 wherein the optical signal is modulated by the modulator when the magnetic device passes the
7 casing collar.

1 78. The locator of claim 77, wherein the modulator is an optical interferometer.

1 79. The locator of claim 77, wherein the magnetic device brings the modulator into alignment
2 with the fiber optic line when the magnetic device passes a casing collar and the optical signal is
3 modulated when the modulator is in alignment with the fiber optic line.

1 80. The locator of claim 79, wherein:
2 a pulse is reflected through the fiber optic line each time the modulator becomes aligned
3 with the fiber optic line; and
4 an acquisition unit receives the reflected pulse and thereby identifies the detection of the
5 casing collar.

1 81. The locator of claim 77, wherein the optical signal is modulated by imparting a strain on the
2 fiber optic line.

1 82. The locator of claim 81, wherein the modulator comprises a fiber-bragg grating incorporated
2 on the fiber optic line.

1 83. The locator of claim 81, wherein the magnetic device comprises a permanent magnet and a
2 coil.

1 84. The locator of claim 81, wherein the magnetic connection generates a voltage that causes a
2 piezoelectric material mechanically coupled to the fiber optic line to constrict and strain the fiber
3 optic line.

1 85. The locator of claim 77, wherein the modulator moves in relation to the fiber optic line to
2 cause the modulation of the optical signal.

1 86. The locator of claim 85, wherein the magnetic device comprises a permanent magnet and a
2 moving magnet and the moving magnet moves in relation to the permanent magnet when the
3 magnetic device passes the casing collar.

1 87. The locator of claim 86, wherein movement of the moving magnet causes the movement of
2 the modulator in relation to the fiber optic line.

1 88. The locator of claim 87, wherein the moving magnet is biased to a stationary position by a
2 spring.

1 89. The locator of claim 87, wherein the modulator comprises a component having alternately
2 placed black and white lines.

1 90. A method of logging a wellbore, comprising:
2 deploying a logging tool in a wellbore that includes at least one fiber optic sensor;
3 sending data from the fiber optic sensor; and
4 transmitting the data to a surface of the wellbore on a real time basis through a fiber optic
5 line that is in optical communication with the fiber optic sensor.

1 91. The method of claim 90, wherein the data comprises at least one measurement of the
2 wellbore environment.

- 1 92. The method of claim 90, wherein the data comprises status of the logging tool.
- 1 93. The method of claim 90, further comprising deploying the fiber optic line within one of a
2 slickline or a braided cable.
- 1 94. The method of claim 92, further comprising deploying the fiber optic line within a conduit.
- 1 95. The method of claim 94, further comprising sending an actuation signal through the conduit.
2 to actuate at least one device located downhole.
- 1 96. The method of claim 95, wherein the actuation signal comprises a hydraulic signal.
- 1 97. The method of claim 96, wherein the at least one device comprises one of a packer, a shaped
2 charge, a flow control valve, a sleeve valve, a ball valve, a sampler, a sensor, a pump, or a tractor.
- 1 98. The method of claim 94, wherein the conduit is a tube.
- 1 99. The method of claim 94, wherein the conduit is a coiled tubing.
- 1 100. The method of claim 94, further comprising attaching the logging tool to the conduit.
- 1 101. The method of claim 94, further comprising deploying the conduit from a reel located at a
2 surface of the wellbore.
- 1 102. The method of claim 101, further comprising positioning the reel on a vehicle.
- 1 103. The method of claim 90, further comprising deploying and retrieving the logging tool
2 multiple times in the same wellbore.
- 1 104. The method of claim 90, further comprising receiving the data in an acquisition unit that is
2 optically connected to the fiber optic line.

- 1 105. The method of claim 90, further comprising:
2 transmitting an optical signal from a transmitter located at a surface of the wellbore to a
3 modulator located downhole; and
4 modulating the optical signal so that the return optical signal is etched with the data.
- 1 106. The method of claim 90, further comprising reflecting a return optical signal back to an
2 acquisition unit with the relevant measurement encoded therein.
- 1 107. The method of claim 90, wherein the fiber optic sensor comprises at least one of a
2 temperature sensor, a pressure sensor, an acoustic sensor, a casing collar locator, a flow sensor, a
3 chemical property sensor, a gamma ray tool, an optical fluid analyzer, a gyro tool, a water detection
4 sensor, a gas detection sensor, an oil detection sensor, a differential pressure sensor, a spectrometer,
5 an inclinometer, a relative bearing sensor, a distributed temperature sensor, a distributed strain
6 sensor, a hydrophone, an accelerometer, a sonic tool, a resistivity sensor, or an induction sensor.
- 1 108. The method of claim 90, wherein the fiber optic line acts as a distributed temperature sensor.
- 1 109. The method of claim 108, wherein the fiber optic line acts as a distributed strain sensor.
- 1 110. The method of claim 90, wherein the fiber optic line acts as an acoustic array.
- 1 111. The method of claim 90, wherein a plurality of fiber optic lines are in optical
2 communication with the logging tool.
- 1 112. The method of claim 90, further comprising sending an optical signal through the fiber optic
2 line actuate at least one device located downhole.
- 1 113. The method of claim 112, wherein the at least one device comprises one of a packer, a
2 shaped charge, a flow control valve, a sleeve valve, a ball valve, a sampler, a sensor, a pump, or a
3 tractor.

- 1 114. The method of claim 105, wherein the modulating comprises imparting a strain on the fiber
2 optic line.
- 1 115. The method of claim 105, wherein the modulating comprises changing an optical path in an
2 optical interferometer.
- 1 116. The method of claim 105, wherein the modulating comprises moving a modulator in
2 relation to the fiber optic line.
- 1 117. A method to calculate the flow of fluid within a wellbore, comprising:
2 providing a spinner adapted to spin when in contact with fluids flowing through the
3 wellbore; and
4 modulating an optical signal transmitted through a fiber optic line depending on the spinning
5 of the spinner.
- 1 118. The method of claim 117, wherein the modulating step comprises aligning a modulator with
2 the fiber optic line once every revolution of the spinner.
- 1 119. The method of claim 118, further comprising determining the velocity of the wellbore fluids
2 based on the frequency of modulations.
- 1 120. The method of claim 117, wherein the modulating step comprises imparting a strain on the
2 fiber optic line.
- 1 121. The method of claim 120, wherein the imparting step comprises:
2 creating a magnetic connection related to the revolution of the spinner; and
3 generating a voltage that causes a piezoelectric material mechanically coupled to the fiber optic line
4 to constrict and strain the fiber optic line.

1 122. A method for identifying the location of casing collars disposed in a wellbore, comprising:
2 providing a magnetic device adapted to become magnetically connected to a casing collar as
3 the magnetic device passes the casing collar; and
4 modulating an optical signal transmitted through a fiber optic line when the magnetic device passes
5 the casing collar.

1 123. The method of claim 122, wherein the modulating step comprises aligning a modulator with
2 the fiber optic line when the magnetic device passes the casing collar.

1 124. The method of claim 122, wherein the modulating step comprises imparting a strain on the
2 fiber optic line.

1 125. The method of claim 124, wherein the imparting step comprises:
2 creating a magnetic connection between the magnetic device and the casing collar when the
3 magnetic device passes the casing collar; and
4 generating a voltage that causes a piezoelectric material mechanically coupled to the fiber optic line
5 to constrict and strain the fiber optic line.

1 126. The method of claim 122, wherein the modulating step comprises moving a modulator in
2 relation to the fiber optic line.

1 127. The method of claim 126, wherein the moving step comprises moving a moving magnet in
2 relation to a permanent magnet when the magnetic device passes the casing collar.

1 128. The method of claim 127, further comprising biasing the moving magnet to stationary
2 position by use of spring.

- 1 129. A system for use in a subterranean well, comprising:
2 a conduit extending from a surface of a well towards a bottom of the well;
3 a fiber optic line located within the conduit;
4 the conduit adapted to transmit an actuation signal to actuate at least one device located
5 downhole;
6 the fiber optic line adapted to transmit an optical signal; and
7 wherein the conduit transmits the actuation signal and the fiber optic line transmits the
8 optical signal at the same time.
- 1 130. The system of claim 129, wherein the actuation signal comprises a hydraulic signal.
- 1 131. The system of claim 129, wherein the optical signal comprises a signal to actuate at least
2 one device located downhole.
- 1 132. The system of claim 129, wherein the optical signal comprises data.
- 1 133. A method for transmitting signals in a subterranean well, comprising:
2 providing a conduit that extends from a surface of a well towards a bottom of the well;
3 providing a fiber optic line within the conduit;
4 transmitting an actuation signal through the conduit to actuate at least one device located
5 downhole; and
6 transmitting an optical signal through the fiber optic line at the same time as the transmitting
7 an actuation signal step.
- 1 134. A system comprising:
2 a fiber optic line; and
3 a device responsive to optical signals in the fiber optic line, the device comprising:
4 a valve responsive to the optical signals; and
5 a chamber, the valve to control communication of fluid between the chamber and a
6 wellbore environment.

- 1 135. The system of claim 134, wherein the device comprises a tracer injection device.
- 1 136. The system of claim 134, wherein the device comprises a sampler device.
- 1 137. The system of claim 136, wherein the sampler device comprises a bottle containing a
2 vacuum prior to opening of the valve.
- 1 138. A system to log a wellbore, comprising:
2 a tool adapted to be deployed in a wellbore;
3 a fiber optic line in optical communication with the tool; and
4 the tool comprising at least one of a temperature sensor, a pressure sensor, an acoustic
5 sensor, a casing collar locator, a flow sensor, a chemical property sensor, a gamma ray tool, an
6 optical fluid analyzer, a gyro tool, a water detection sensor, a gas detection sensor, an oil detection
7 sensor, a differential pressure sensor, a spectrometer, an inclinometer, a relative bearing sensor, a
8 distributed temperature sensor, a distributed strain sensor, a hydrophone, an accelerometer, a sonic
9 tool, a resistivity sensor, an induction sensor, a spectrometer, a refraction measurement device, a
0 tracer injection tool, a packer, a shaped charge, a flow control valve, a sleeve valve, a ball valve, a
1 sampler, a sensor, a pump, and a tractor.